New LCA Theses

Comparative Evaluation of Life Cycle Assessment Models for Solid Waste Management

Jörg Winkler

Dr. Jörg Winkler, Sansibarstrasse 22, D-13351 Berlin, Germany (joerg.winkler@berlin.de)
(Institute for Waste Management an Contaminated Sites Treatment, TU Dresden: http://www.tu-dresden.de/fghhiaa)

DOI: http://dx.doi.org/10.1065/lca2005.02.004

About ten years ago scientists began developing general models to perform life cycle assessments for waste management systems. Instead of starting from scratch for each case study, the models provide the most important waste management processes. The purpose of developing these models was not only to speed up the analysis, but, more importantly, to promote the use of life cycle assessments. The models enabled decision makers and waste managers to use life cycle assessments for their specific waste management system without in-depth knowledge of the methodology and allowed them to learn how changes in the system affect the environmental impacts through scenario analysis. Moreover, applying these models to several waste management systems allows one to determine which system shows the best performance from a environmental point of view.

The increased use of the models in case studies made one general issue of life cycle assessment more and more apparent. Due to the nature of an assessment, it is impossible to directly prove the validity of the results and draw conclusions. For example, it is impossible to observe greenhouse gases emitted from a landfill and their impact on the environment over the whole life cycle due to the extraordinarily long periods involved. Critics disapproving of a specific study or the methodology itself tend to exploit this weakness to question the results. Although peer-reviews and requests for a complete documentation of the assumptions and definitions, as well as sensitivity analysis, have helped to improve the credibility of life cycle assessment studies, one especially important aspect has not yet been covered. For a more profound discussion on the issue, it is necessary to show that life cycle assessments done with the tools developed by different researchers do not lead to different or even contradictory conclusions and that variations in results of the life cycle assessments are within an acceptable range.

By modelling one specific case, the waste management system of Dresden (capital of Saxony, Germany), against several models, and by comparing their life cycle assessment results, it was possible to investigate this issue. Three different scenarios were designed to evaluate several waste treatment technologies: landfill, incineration and materials recovery facility.

The models covered by the comparison are:

- ARES (Germany)
- EPIC/CSR: Integrated Solid Waste Management Tools (Canada)
- DST: Decision Support Tool (US EPA)
- IWM2: Procter & Gamble: Integrated Waste Management 2 (UK)
- ORWARE (Sweden)
- UMBERTO (Germany)

The comparison of the life cycle inventory (LCI) results revealed that the variations in the results provided by each model for each emission are quite significant. On the average, the relative spread over all emissions to air and water from the three modelled scenarios is 310%. Especially the results for heavy metals show a high degree of variation. The LCI results of the landfill scenario for cadmium to air, for example, show a very high relative spread of 1,596%. The same was found for lead emissions to water (754%) for the incineration scenario. But these exceptional outliers vary between the scenarios and the models, which shows that there is no fundamental modelling issue with a specific emission or parameter.

Summarising the results of the three scenarios and comparing the scenarios to one another, some similar patterns can be found concerning the different models. The ARES and the EPIC/CSR models both tend to overestimate certain emissions. Additionally, the EPIC/CSR model underestimates a high number of emissions in comparison to the other models' results. The DST model not only calculates most of the minimum results, it also tends to produce exceptional results which do not fit into the overall picture. The results of the IWM2 are the least extreme, followed by ORWARE. The UMBERTO model delivers a mixed picture. UMBERTO tends to overestimate the LCI emissions in the landfill scenario, whereas it tends to underestimate the emissions in the MRF scenario.

The following break-down of the LCI results provided by the models into the contributions of each waste management process to the total emissions revealed the sources for the differences found. This detailed analysis was focused on four emissions: CO_2, SO_X and Pb emissions to air and Hg emissions to water.

The most important finding of the analysis is that the LCIs calculated by the models are mainly influenced by only one or two major processes of a waste management system. In most cases, these are the waste treatment process (landfill, incineration or MRF) and the allocation for recovered energy and materials; although the variations of the results is comparatively moderate on the level of the waste treatment processes. The high differences in the results for the allocation procedures distorts the results. In nearly every case, it was found that the contribution of the waste collection and transport of residues have an insignificant impact on the total results.

In difference to the other three emissions analysed, the results for carbon dioxide emissions of the waste treatment processes are a remarkable exception. Their variation is much lower and within an acceptable range than these of the other three substances with a relative spread for landfill of 60%, incineration of 13% and MRF of 68%. Notably, in the case of the landfill, further discussions on modelling the anaerobic and aerobic degradation processes are needed, especially with a focus on the dependencies between CO_2 and CH_4.

The analysis of emissions calculated for the two selected heavy metals (Pb to air, Hg to water) make it clear that the modelling approaches for these are very different. In some models, these emissions are mainly determined by the waste management process and in others by the allocation procedures. Even more important is that for some other processes, such as waste collection, the heavy metal emissions are often not modelled. The lack of data, even for such generally well understood issues as vehicles emissions, is a severe problem for the validity of the LCI results calculated by the models. Looking at data for other emissions, it was found, as a general rule, that the smaller the total amount of emissions, the more severe the influence of lacking data on the LCI is. The importance of this issue becomes clear when the life cycle assessment phase is considered. In many cases, relatively small emissions of certain substances have a relatively high impact on the environment (e.g. dioxins for ecotoxicity).

In an exemplary analysis, it was studied how the differences found on the level of the life cycle inventory effect the life cycle impact assessment. It became clear that the high variations found in the LCIs and the LCIA are further increased by the different approaches to the scope of the LCI. This is an especially sensible issue for LCA practitioners using the models who are often not aware of the choices that developers of the models have made on the scope of the LCA and how these

© 2005 ecomed publishers (Verlagsgruppe Hüthig Jehle Rehm GmbH), D-86899 Landsberg and Tokyo • Mumbai • Seoul • Melbourne • Paris

might affect the life cycle assessment of their case or scenario. A detailed documentation of the models can help to sensitise LCA practitioners, but the conclusions drawn on the environmental performance of a waste management system and the comparability of case studies remain questionable.

For this reason, and to get a better understanding how the models work, a sensitivity analysis to the changes in the amount of waste and to the composition of the waste was conducted. It was found that the LCI results are directly correlated to the amount of waste being treated by the waste management scenario. In general, all models show 100% sensitivity to the total emissions to the amount of waste being treated, with some minor deviations. This sensitivity analysis revealed a linear modelling approach which is clearly an oversimplification of the real conditions in a waste treatment process such as an incinerator or a landfill. Regarding the sensitivities of the models of LCI results to the waste composition, it was found that some models show a very detailed modelling approach such as the EPIC/CSR, DST and IWM2 model. In general, this approach leads to less extreme sensitivities for certain materials, but which still occur regardless. Although, the more simplified approach of the ARES and UMBERTO models to not differentiate between the emissions for the materials, comparisons of the total results shows that the LCI results are comparable to those of the other four models, for a common or 'normal' waste composition. Furthermore, it was found that heavy metal emissions, especially, are determined mainly by small fractions in household waste, such as metal and plastic fractions, resulting in high sensitivities to changes in these fractions.

Although the models have gone from the scientific world into a widespread practical application, the comparisons show that the validity of the LCA data calculated by the models must be significantly improved. This can only be achieved by sharing more of the data and modelling methodology. Moreover, better ways of ensuring the validness and quality of the data in the models must be found.

Keywords: Environmental impacts; model comparison; municipal solid waste; waste management

New LCA Theses

Life Cycle Assessment of Products-Environmental Management Tool

Study of Implementation in Romania

Nicolae Peiu

Environmental Protection Agency, Iasi , Romania (nicolaepeiu2001@yahoo.com)

In the introductory part of the thesis environmental problems generated by the development of the social and economic systems are presented, from global to local level, as well as concepts and tools of environmental management used to tackle these problems, followed by an exhaustive presentation of Life Cycle Assessment (evolution and present status as a result of the development of ISO-14040 series of standards).

The goal of the thesis is to contribute to the implementation of LCA in Romania. In order to achieve it, the following four case studies representing the main part of the thesis have been analysed:

1. Life Cycle Inventory Study of the production of electrical energy in Romania
2. Life Cycle Assessment Comparative Study of some alternatives for transport in Romania
3. Life Cycle Assessment Comparative Study of some alternatives for the production of thermal energy in Romania
4. Life Cycle Assessment Comparative Study of some alternatives for the production of edible oil in Europe

This precise order of the case studies was necessary because the results of the first case study have been used in the second, the results of first and second in the third and so on…

The first three case studies are related because they deal with the energy carriers of life cycles combined with power plant life cycles (first study), vehicle life cycles (second study) or thermal power plant life cycle (third study). In the fourth case study, on the one hand, the comparison is focused on the achievement of the product from two different plants (sun flower and soy bean), and, on the other hand, the influence of some different locations and some different technological levels (upgraded technology in comparison with an old technology). By the collection or processing of data for these four case studies and a special section dedicated to these LCA data, the thesis initiates the achievement of a LCA database for Romania.

In the three case studies, in which the Life Cycle Assessment is performed (the first case study is limited only to an Life Cycle Inventory representing, in conformity with ISO 14040 standard, an LCA without Life Cycle Impact Assessment), four of the best known methodologies for LCA have been used: Eco Indicator 95, Eco Indicator 99, EDIP and EPS. In order to use EDIP methodology, it was necessary to establish some normalization and weighting factors specific for Romania for the regional and local impact categories. For the other three methodologies, global normalization factors have been used (or the factors identified for these methodologies). The results of the application of the four methodologies have shown that LCA studies are replicable, repeatable and can be achieved without insurmountable difficulties.

The results of the four methodologies used in case studies are not identical, due to different characterization, normalization and weighting factors, or sometimes even some different impact categories for each of these methodologies. On the whole, the results show a good equivalence that confirm and increase their credibility.

The improvement of the environmental performance of the product/service can be achieved in two ways: a) by focusing on the most relevant step within the life cycle of a specific product (the comparison of unit processes within the life cycle of a product); b) stimulating environmental-friendly products with the promotion of better alternatives (comparison of products). Both these directions are approached in all the four case studies of the thesis establishing the alternative options that are producing the smallest interventions on the environment and the life cycle steps in which priority interventions are necessary for the reduction of these interventions. Thus, all the studies have shown, for the energy carriers' life cycles, that the emissions on the environment are predominant in the consumption (combustion) step. But the electrical vehicles from the second case study are more polluting than the other vehicles, because the production of electricity in Romania in the preconsumption phase is more pollutant than the processes of preconsumption and consumption of the other fuels.

Representing the first substantial contribution in the field of LCA in Romania, the thesis grounds the implementation of this environmental management technique in the country.

Nicolae Peiu is a graduate of the Geochemistry Department of "A. I. Cuza" University in Iasi, Romania. He is currently working at the Environmental Protection Agency of Iasi county which represents the local government authority of the Ministry of Environment and Water Management of Romania.
The thesis has been defended on 4th of June 2004 with 'cum Laude'.

© 2005 ecomed publishers (Verlagsgruppe Hüthig Jehle Rehm GmbH), D-86899 Landsberg and Tokyo • Mumbai • Seoul • Melbourne • Paris